Ocean acidification explored using a suite of end-to-end ecosystem models covering ecosystems from the tropics to the arctic

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Ocean Futures Under Ocean Acidification, Marine Protection, and Changing Fishing Pressures Explored Using a Worldwide Suite of Ecosystem Models

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Overview of talk

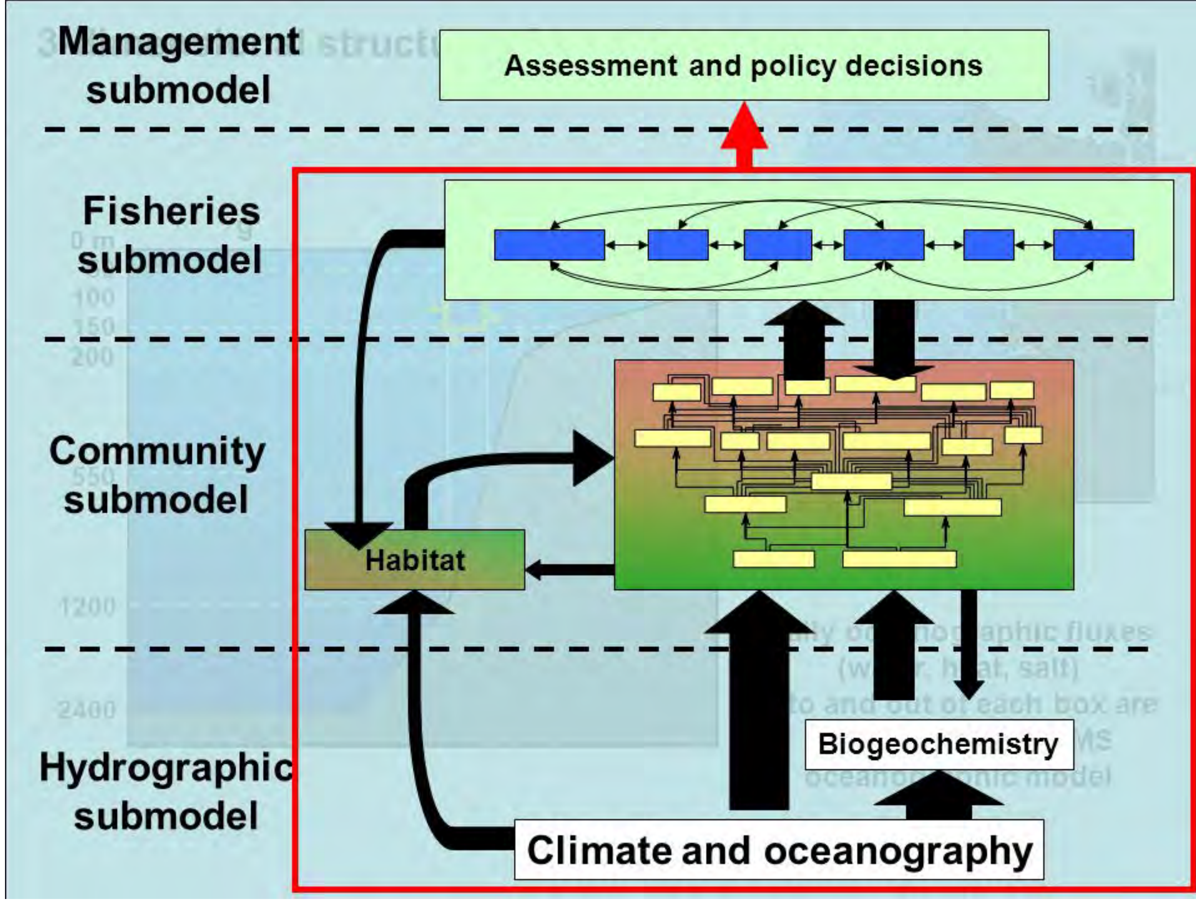
- Background and rationale for using End-to-end ecosystem models in EBM
- Common scenarios
- The models
- Analyzing the results: guilds and emergent ecological properties
- Ocean Acidification
- Marine Protection
- Fisheries
- Ecosystem responses
- Conclusions

Background

- EBM requires evaluating effects of **multiple stressors** at once on the **entire ecosystem**
  - Need trade-off analyses illustrating the ecosystem-wide effects of management actions
- To address global issues we need to understand and compare how stressors and management actions work in different regions to tease out the common as well as unique responses
- Only feasible using modelling approaches

Atlantis end-to-end model framework

- Complex ecosystem model covering everything from energy input to human activities
- Full MSE capability, while taking into account fisheries, climate and environmental variability, and multi-sectoral dynamics
- >26 extant models (more in development)

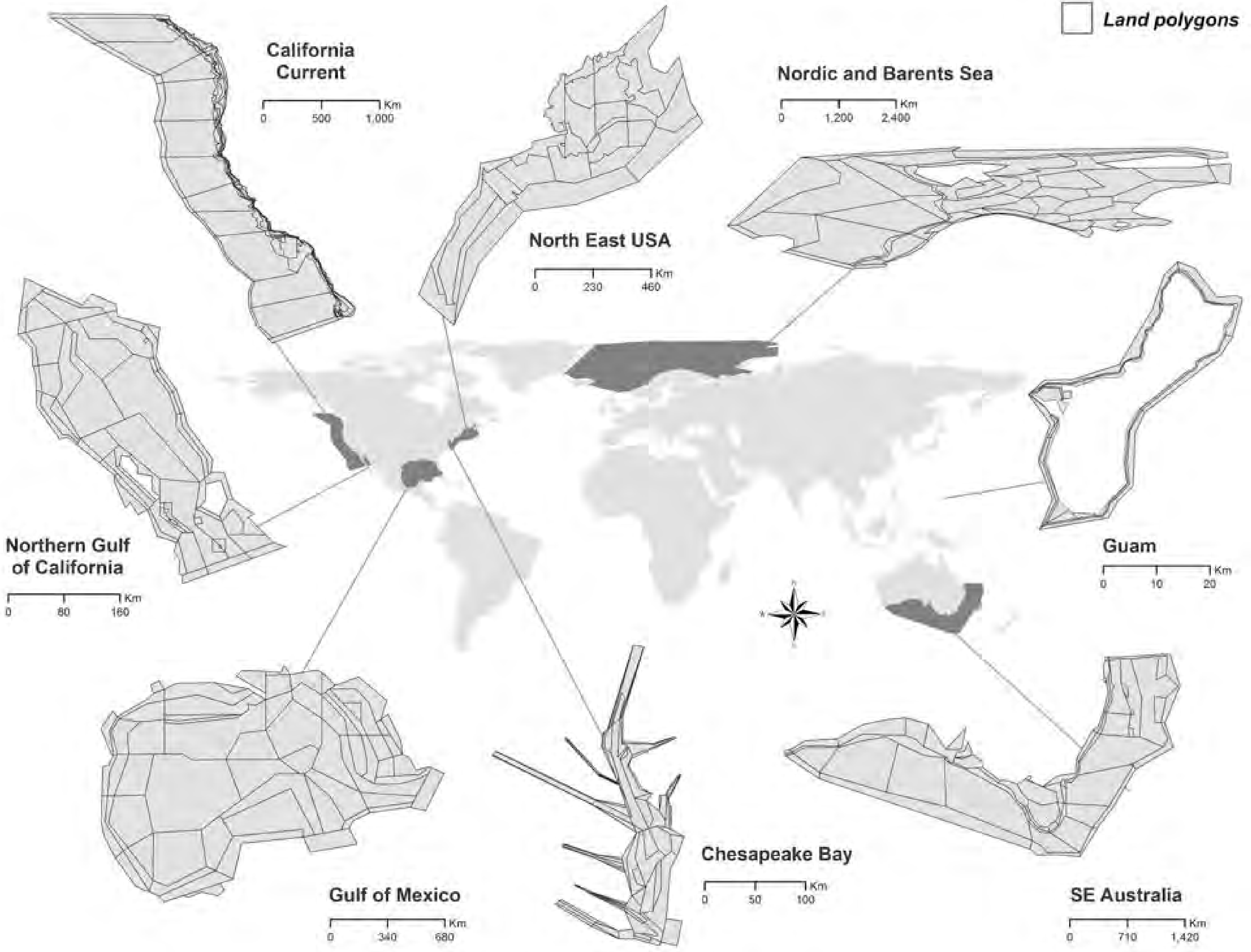


Weijerman et al. 2016

Common scenarios - 50 years into the future

1. **BASE CASE** (the one all the others were compared to)
    1. Calibrated and published model
    2. Fisheries continue at constant rate
2. Increased **OCEAN ACIDIFICATION**
    1. 0.5% or 1% added mortality pr day for calcifying algae, corals, coccolithophores, echinoderms, and mollusks
3. Increased **MARINE PROTECTION**
    1. MPAs were extended from shore to 250m until 10, 25, and 50% of the continental shelf was closed to all fishing
4. Changing **FISHING PRESSURES**
    1. Fishing mortality rates (*F*) on species fished in the base-case scenario were doubled, halved, and eliminated

The eight Atlantis models



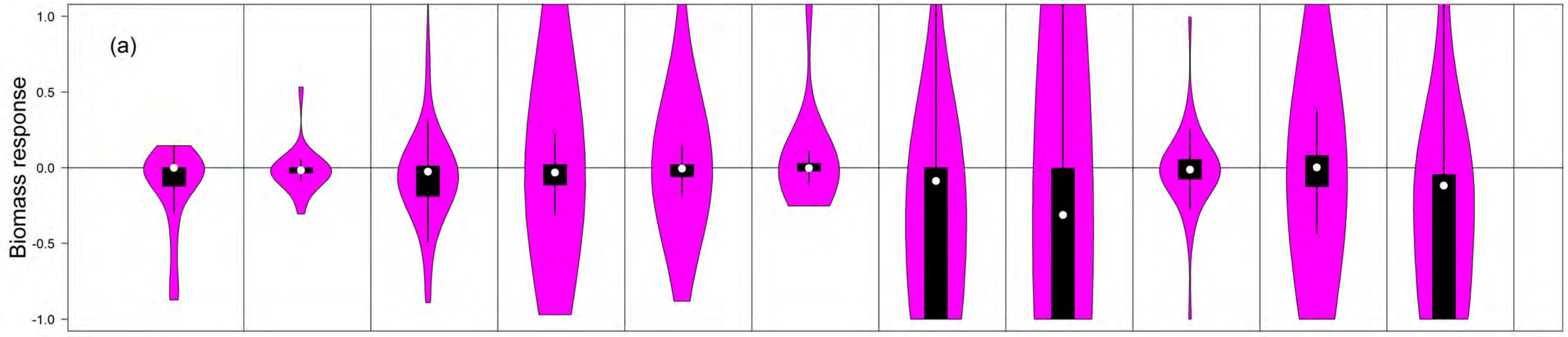
Analyzing the results

- Species were aggregated to **Guild Level** – since the biological components (species) differed between the models:
    - Marine Mammals
    - Seabirds
    - Sharks
    - Demersal fish
    - Squid
    - Filter feeders
    - Epibenthos
    - Zooplankton
    - Primary production
    - Infauna
- Emergent ecosystem properties analyzed through indicators:

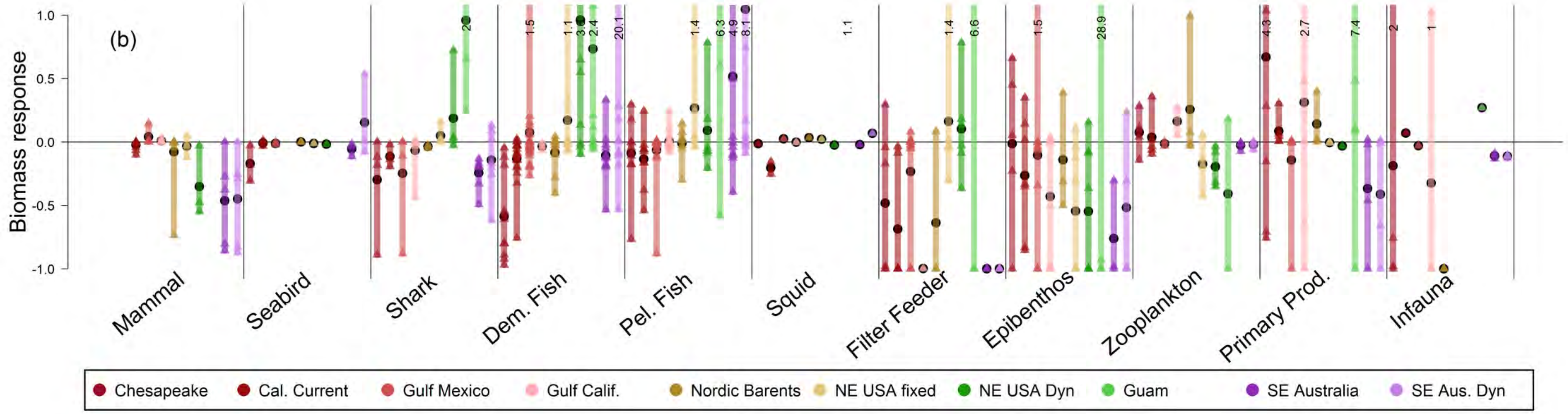
Ecological & Fishery indicators

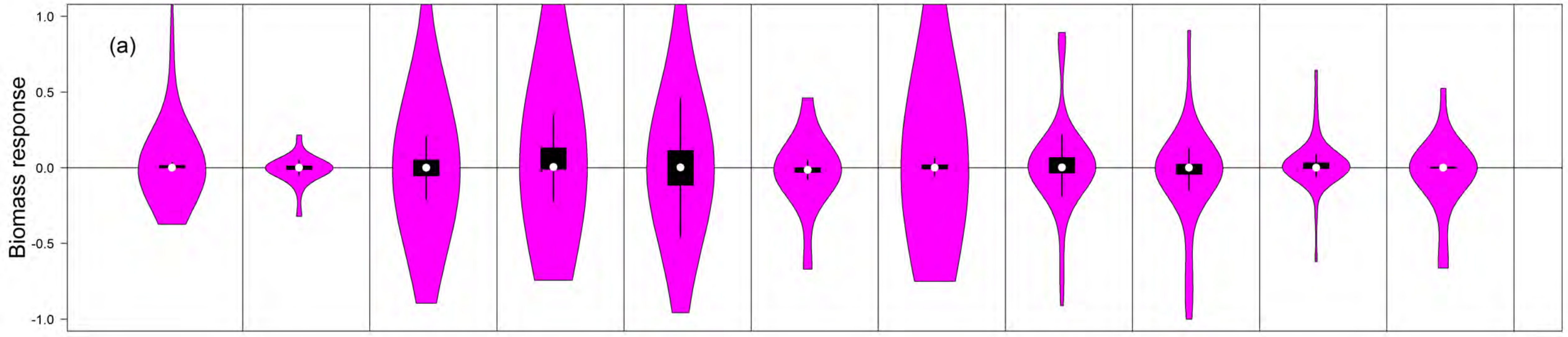
Ecological indicators	
Pel bio/PP	Ratio of pelagic biomass to primary production
Bio/PP	Ratio of total biomass to primary production
MTL bio	Mean trophic level (MTL) of biomass
Predfish prop	Proportion of fish biomass that is predatory fish
Dem/pel fish	Ratio of demersal to pelagic fish biomass
Dem/pelagic	Ratio of total demersal to total pelagic biomass
Dem bio/PP	Ratio of demersal biomass to primary production
Fishery indicators	
Pel catch	Catch of pelagic species
Total catch	Total catch
MTL catch	Mean trophic level of catch
Fish exp rate	Exploitation rate (summed catch / summed biomass) of fish only
Exp rate	Exploitation rate of all targeted species biomass
Value	Value of catch
Fish cat	Catch of all fish
Dem cat	Catch of demersal species

Results

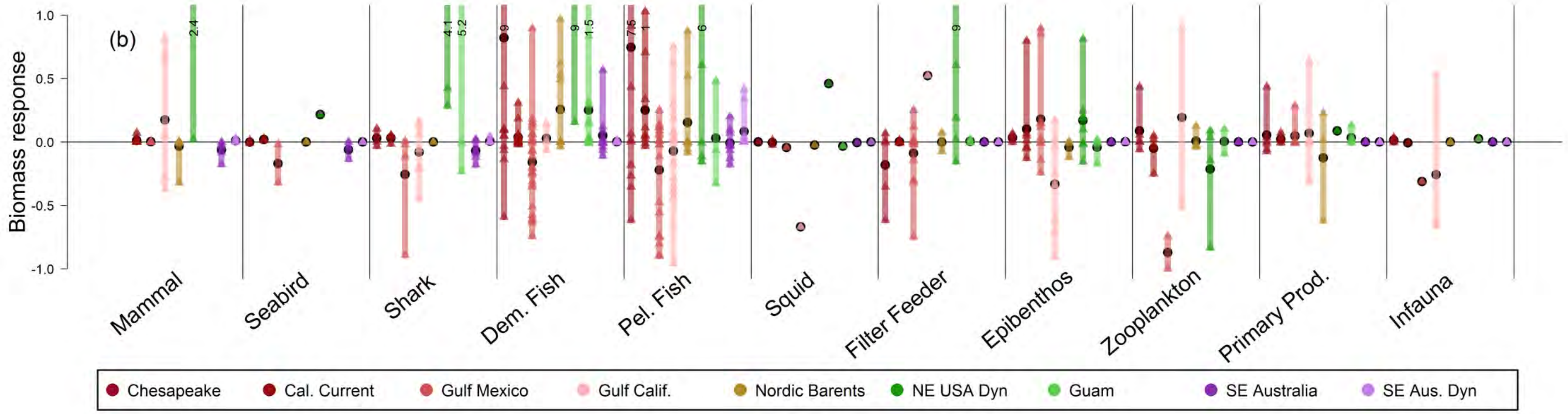


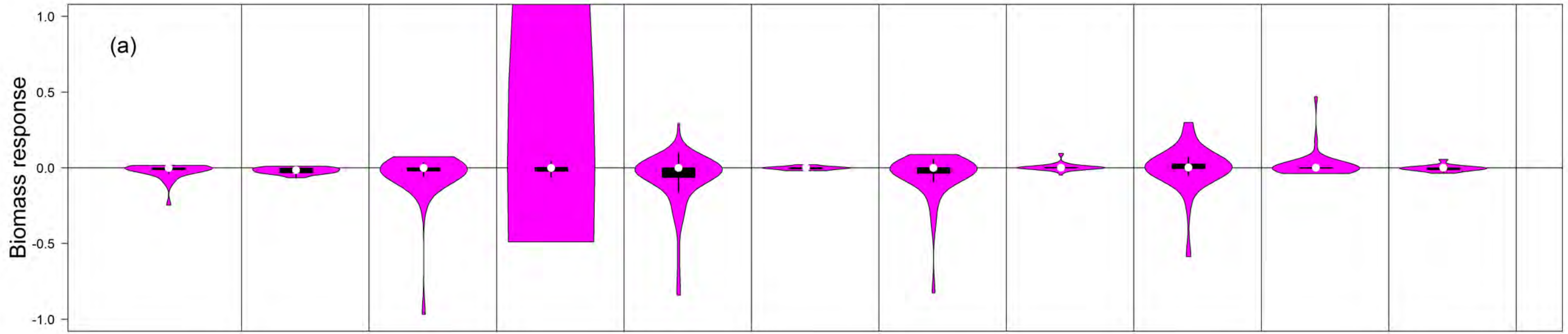
Ocean Acidification (1% added mortality per day)



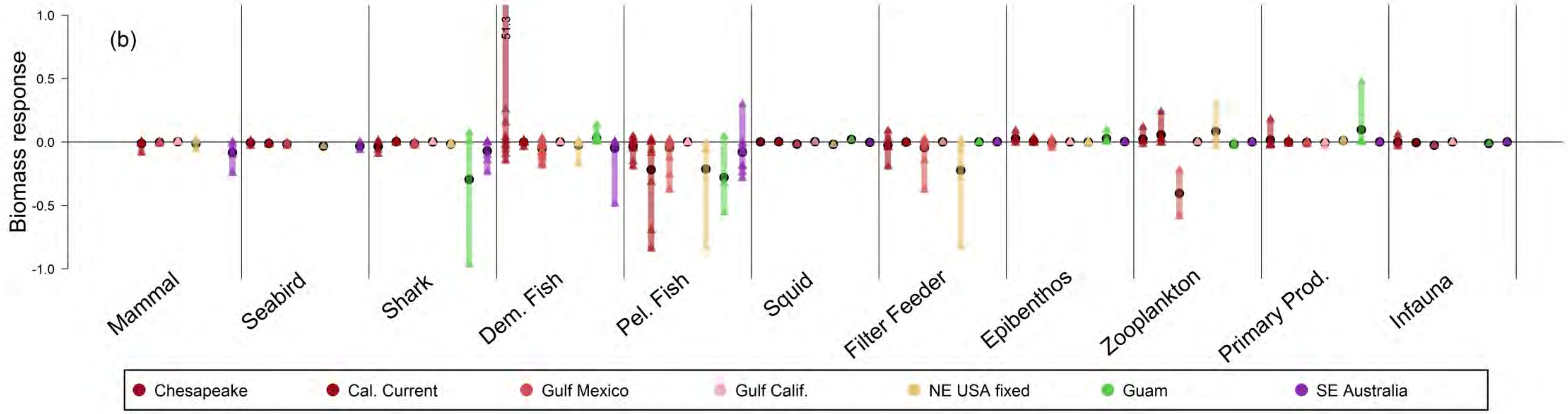


Marine Protection, 50% closures of continental shelf

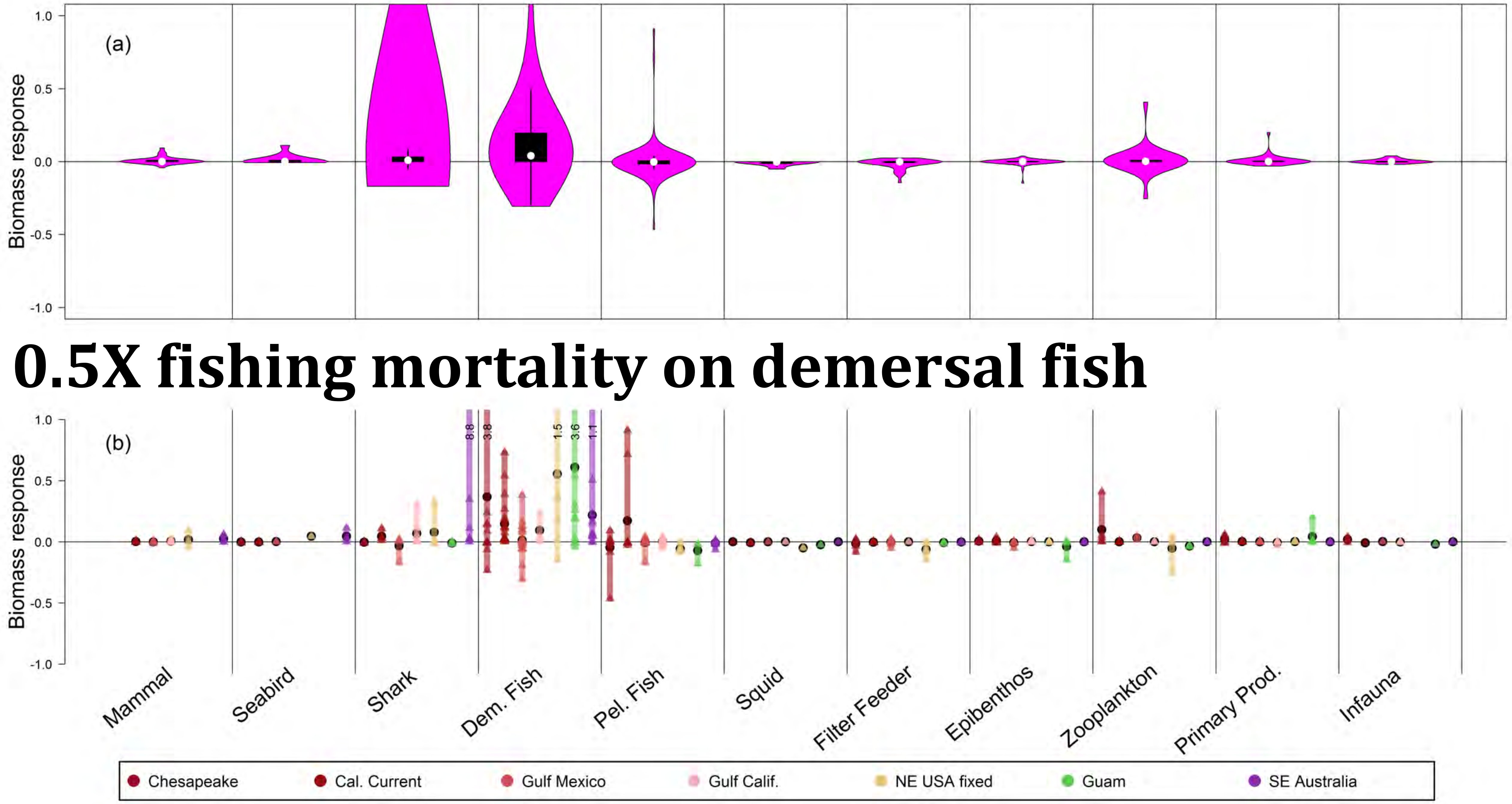




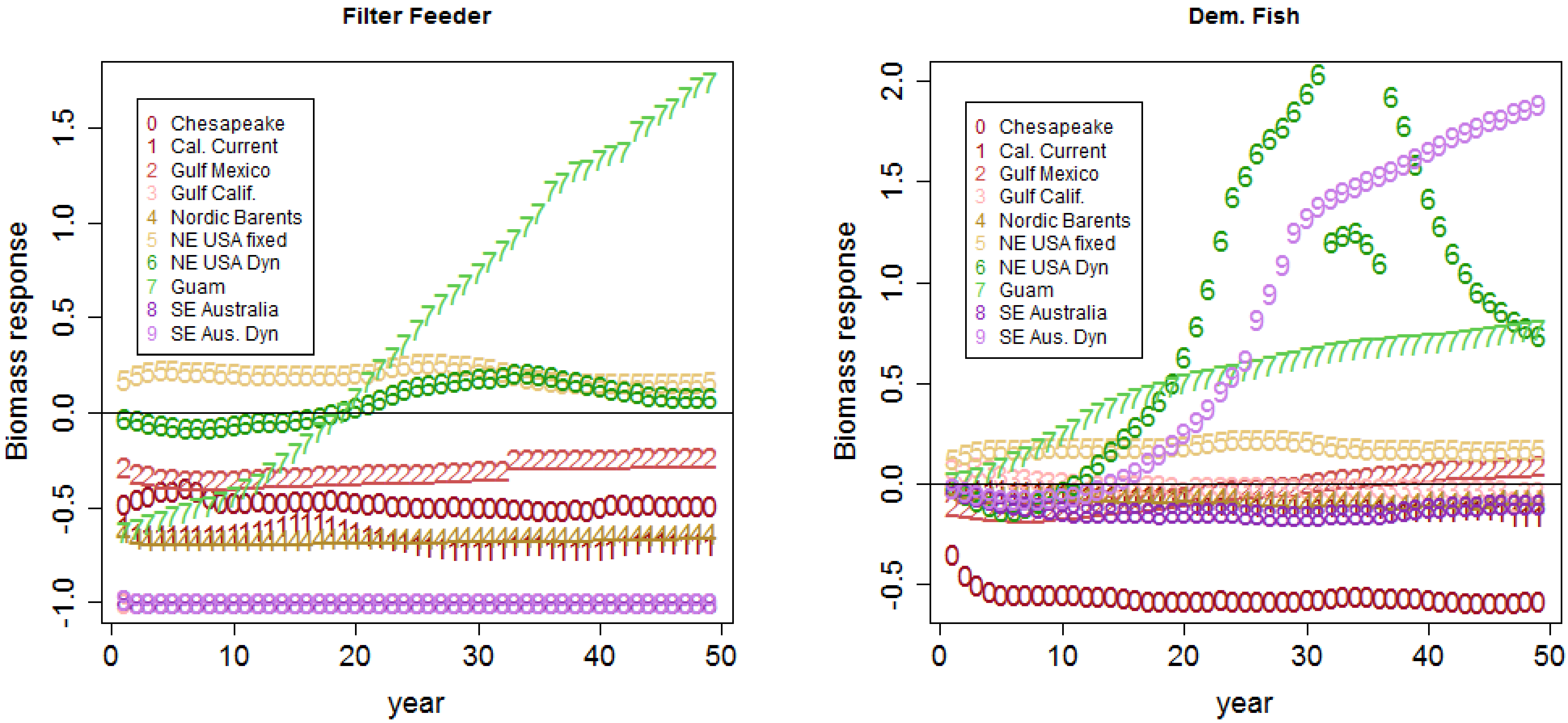
2X fishing mortality on small pelagic fish



0.5X fishing mortality on demersal fish



Guild level responses to OA over time

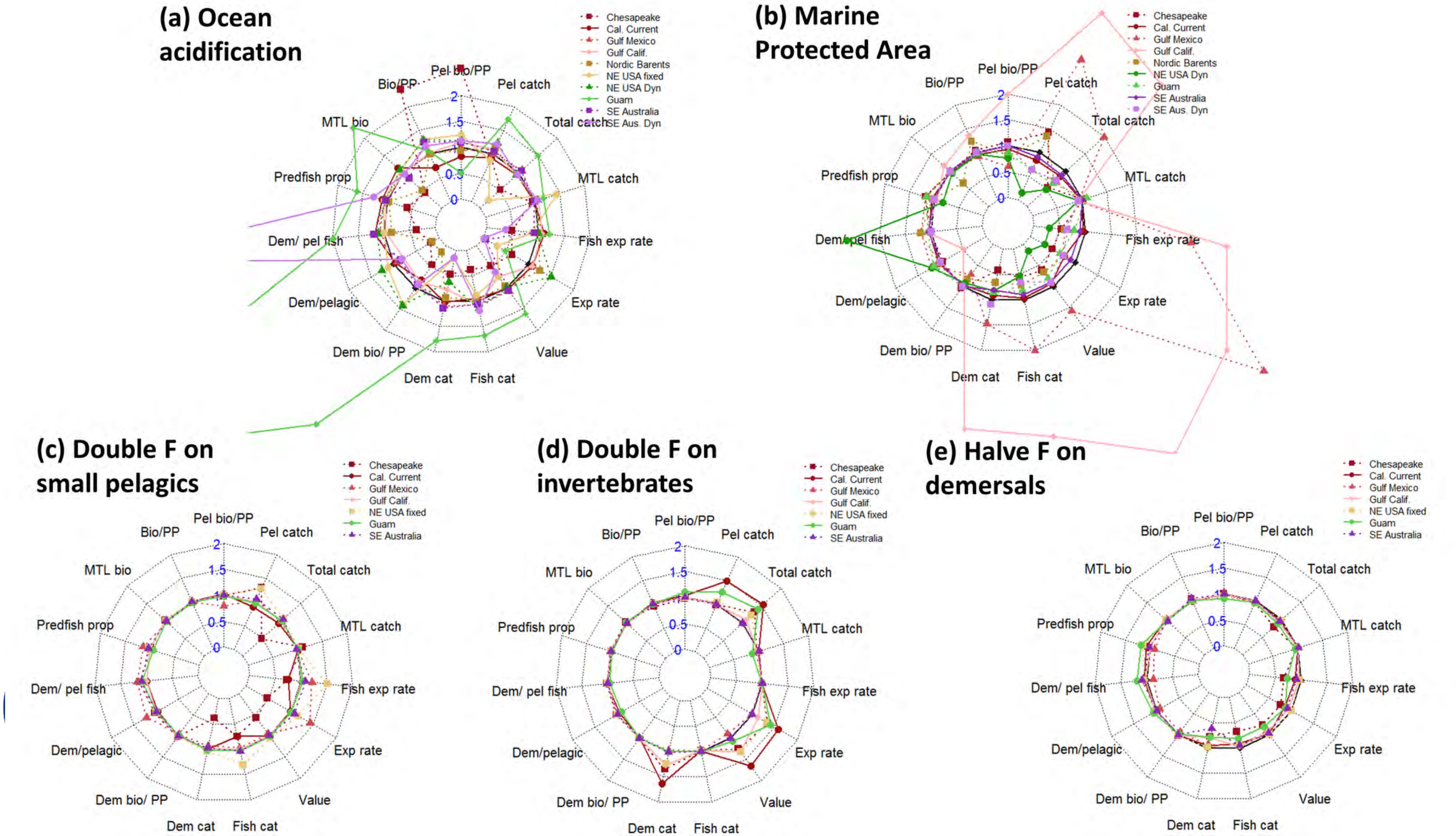


OA results explained

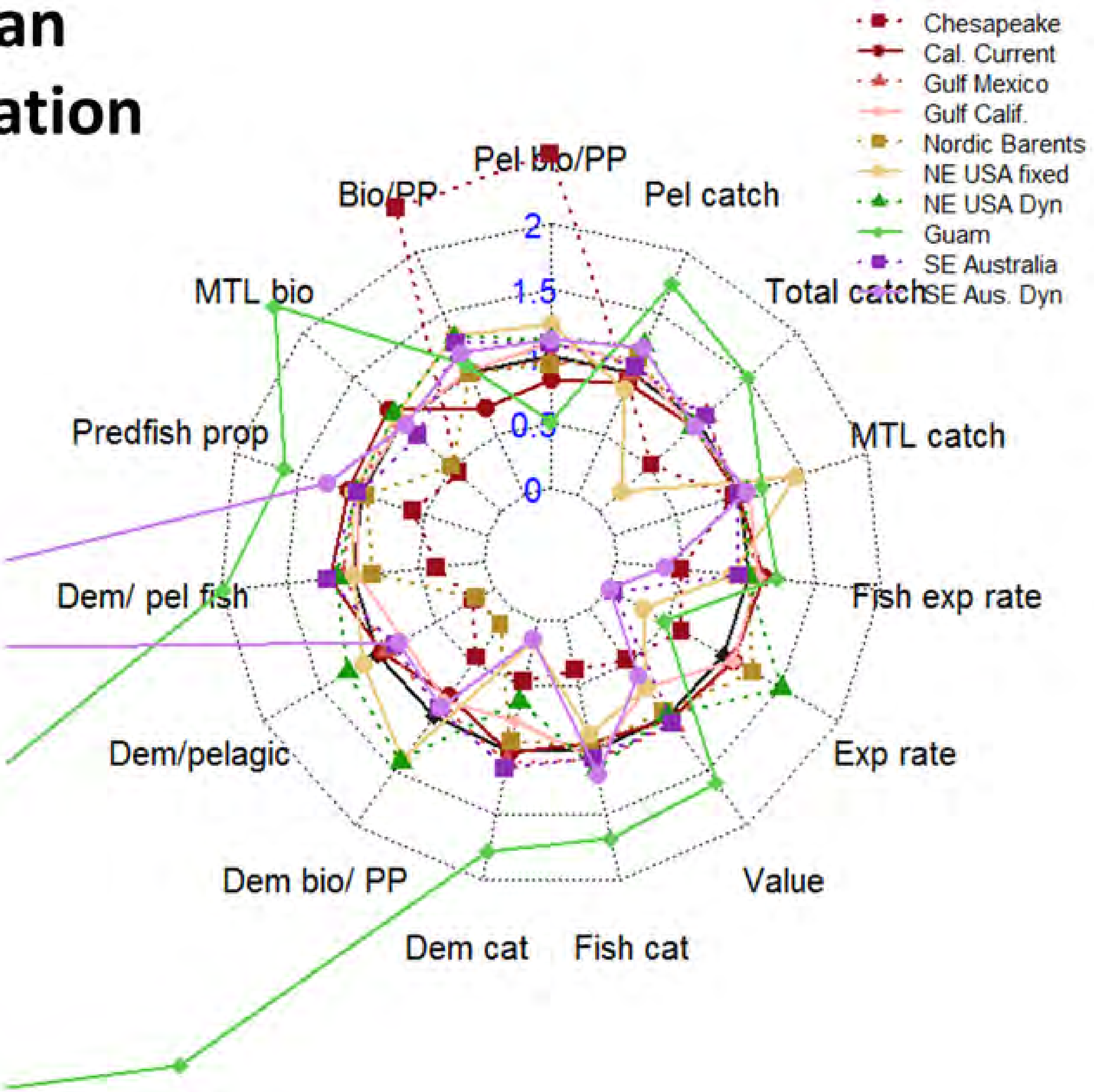
- Most models showed an overall decline in guild biomass under OA scenarios

- **Regime shifts apparent in:**
- Guam
  - Corals and CCA decline massively, but soft corals (& other filter feeders) move in coupled with increase in detrivores. This provides more food for the fish
- SE Australia
  - Reducing scallops, benthic filter feeders and benthic grazers, but microfauna and detritus increase providing food for red prawns (2000X increase) which in turn provides food for shallow demersal fish that increas 20X
- NE US
  - Weaker impacts than Fay et al (2017) predicted, because Fay added OA mortality to deposit feeders

Indicators and emergent system properties



(a) Ocean acidification



Further developments

- Combining the drivers – current analysis looks at each driver separately.
- Adding more drivers (temperature increase, petroleum activities, pollution)
- Sensitivity testing (difficult, but needed)
- Socioeconomic effects of displacing fishing effort (caused by changes in species distribution and MPAs)

Conclusions

- Stronger impacts from ocean acidification and MPAs than fishing
  - Regime shifts happened in Guam and SE Australia
  - Sensitive to what species are defined to be impacted by OA
- Vast majority of impacts are moderate
- Managing at the guild level, taking advantage of greater stability there, merits further consideration
- Removing fishing causes larger impacts than doubling fishing effort
- Clearly illustrate how ecosystem modelling can be used to highlight the most interesting management action among a suite of possible alternatives

Thanks to all my coauthors, and thank you for your attention!

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Paper available at: https://www.frontiersin.org/articles/10.3389/fmars.2018.00064/full